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ON THE RESISTANCE TO DESICCATION OF THE INTERMEDIATE HOST OF SCHISTOSOMA JAPONICUM KATSURADA

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In an earlier paper (Cort, 1919: 489) I noted that specimens of *Blanfordia nosophora* (Robson), the intermediate host of the Japanese blood fluke, *Schistosoma japonicum,* which had been shipped from Japan to California in a dried condition, became active when placed in water. This resistance to drying is possible because *Blanfordia nosophora* is an operculate snail and is able to close the opening of its shell with its operculum. In this connection it seemed important to determine the degree of resistance to desiccation of this species of snail. The practical significance of definite data on this point is evident, since the destruction of the snail intermediate host is a promising line of attack in the control of any trematode parasite of man. Material for taking up of this problem became available when on June 23, 1919, I received through the kindness of Dr. S. Yoshida, of the Osaka Medical College, a large number of dried specimens of *Blanfordia nosophora* which had been collected in Japan May 28. Examination showed that over 85 per cent. of these snails were still alive, and that about 4 per cent. of the living snails were infected with the cercariae of *S. japonicum.*

The method of carrying on the experiments involved in this problem was as follows: The dried snails were carefully counted out in lots of one hundred and examined at intervals ranging from one to several days (Table 1). Each hundred snails at the time set for examination was placed in a beaker of water. After about fifteen minutes the snails would begin to emerge from their shells, and inside of two hours almost all of the living ones would be active. These snails were then crushed in watch glasses and examined carefully with a microscope for schistosome cercariae. The snails which had shown no signs of life after two or three hours were kept over night in the water. If any more proved to be alive they were also examined microscopically. In part of the examinations made during the first two weeks of the work, that is up to July (Table 2), the snails which showed no signs of life were also crushed and examined with a microscope. They were found without exception to be dead.

In my experiments the attempt was made to answer the following questions: First, how long can specimens of *Blanfordia nosophora* live in the dried condition? And second, do snails infected with the cercariae of *S. japonicum* show less resistance to desiccation than uninfected ones?

TABLE 1.—DATA SHOWING RESISTANCE TO DESICCATION OF BLANFORDIA NOSOPHORA

Date of Examination	Number of Days after Snails Had Been Dried	Number of Snails Examined	Number of Living Snails	Number of Living Snails Infected with Cercariae of S. japonicum
June 25	28	100	86	4
June 26	29	100	87	3
June 26	29	100	82	1
June 27	30	100	91	4
June 27	30	100	90	1
July 5	38	100	80	1
July 5	38	100	83	2
July 6	39	100	76	1
July 7	40	100	81	1
July 7	40	100	77	1
July 9	42	100	76	2
July 11	44	100	71	0
July 14	47	100	62	0
August 7	71	100	12	1
August 7	71	100	8	0
August 12	76	100	2	0
August 22	86	100	0	0
August 24	88	100	0	0

The data given in Table 1 shows that the length of life of *Blanfordia nosophora* in the dried conditions is comparatively short. From the fourth to the seventh week after the snails had been taken out of the water, June 25 to July 14, there was a distinct decrease in the number of living individuals. After ten weeks, August 7, only a small percentage of the snails were found to be alive, and finally in less than three months, August 22, all individuals were found to be dead. This last result was corroborated by data from two other entirely distinct batches of material of *Blanfordia nosophora.* A number of specimens were set aside from snails which were taken out of the water in Japan on March 27. On August 7, when this material was examined, all of the snails were found to be dead. Further material comprising about a pint of dried snails was brought from Japan by Dr. S. Yoshida. All were found to be dead when they were placed in water three months after they first became dry.

Table 2 contains seven one hundred lots taken from Table 1 in which microscopical examinations were made of the dead snails, as well as of the living. A large proportion of the dead snails were simply empty shells. Part of them, however, had apparently only recently died, and in some of these it was still possible to detect the infection with the cercariae of *S. japonicum.* Of the 700 snails included in Table 2, 573 were found to be living and 127 dead. I have no record of how many of these 127 dead snails were merely empty shells. The table shows that 11 of the living snails, or 1.9 per cent., and that 7 of the dead snails, or 5.5 per cent., were infected with cercariae of *S. japonicum*. Since a large number of the dead snails were merely empty shells the proportion of infected snails among those which had died during the course of the experiment was much greater than 5.5 per cent. These figures certainly indicate a more rapid death rate among infected than uninfected snails.

TABLE 2.—DATA ON LOTS IN WHICH BOTH LIVING AND DEAD SNAILS WERE EXAMINED FOR INFECTION WITH THE CERCARIAE OF S. JAPONICUM

Date of Examination	Number of Days after Snails Had Been Dried	Number of Snails Examined	Number of Living Snails	Number of Living Snails Infected	Number of Dead Snails	Number of Dead Snails Infected
June 25	28	100	86	4	14	2
June 27	30	100	90	1	10	1
July 5	38	100	80	1	20	2
July 5	38	100	83	2	17	0
July 6	39	100	76	1	24	2
July 7	40	100	81	1	19	0
July 7	40	100	77	1	23	0

The data (Table 1) also show a distinct reduction in the percentage of infection in the living snails during the course of the experiment. In the first 500 snails examined, June 25 to June 27, the percentage of infection of living snails with the cercariae of *S. japonicum* was 3.44 per cent. In the second 500-snails examined eight days later, July 5 to July 7, the percentage of infection in living snails was only 1.51 per cent. On the other hand a striking case of resistance of an infected individual is shown in the first 100 snails examined on August 7 (Table 1), in which one infected individual was found out of 12 still living after the snails had been in the dried condition for ten weeks.

It was evident, however, that desiccation unfavorably affected the cercariae of *S. japonicum* within the snail host. All cercariae taken from snails which had been dry for a month or more were somewhat shrivelled and inactive. Many of these cercariae became plump and active after being in water for a while. Quite a number of cercariae, however, in each of these infected snails were permanently injured, and in some cases almost all the cercariae in a snail would be rendered entirely inactive. The conclusion can therefore be drawn in regard to the second question proposed, that not only are the infected snails less resistant to desiccation than the uninfected, but that the cercariae are injured and sometimes killed by a length of time in the dried condition that their host is able to resist.

It is perhaps significant to note in this connection certain habits of *Blanfordia nosophora* which are related to its resistance to drying. I have found it difficult to keep snails active in aquaria. They keep constantly climbing out of the water and drying on the glass. They became almost immediately active again when pushed back into the water. This habit of crawling out of the water seems to be related to unfavorableness of environment in the aquaria. In those aquaria in which there was present a considerable amount of food material, as indicated by a slight bacterial film on the surface of the water and in which the water was kept well aerated, very few of the snails crawled above the water. On the other hand, in aquaria containing little food material or in which the water was foul, almost all the living snails would soon be found dry above the surface of the water. It was possible to determine whether a given aquarium offered a favorable environment or not by the number of snails which remained active under the water. It is evident that this habit of going out of the water to escape unfavorable conditions would be of importance in maintaining the numbers of this species of snail in an environment such as the rice fields of Japan, where there are many changes in the level and the condition of the water. It would also make it difficult to destroy the snails in any given body of water, by the introduction of chemicals.

The data obtained from the experiments recorded in this paper have a definite relationship to measures for the control of Japanese schistosomiasis. The snail intermediate host has long been considered a vulnerable point for attack in the life cycle of digenetic trematodes injurious to man. In the fight against the sheep liver fluke, *Fasciola hepatica,* the killing of the snail intermediate host and the destroying of its breeding places by draining infected pastures, has always been the most effective measure of control. Leiper (1915) advocates this same method in the control of schistosomiasis in Egypt. He suggests that all temporary pools or ditches which harbor the intermediate hosts of *Schistosoma haematobium* and *Schistosoma mansoni* be drained. Since these snails are non-operculate and have little resistance to desiccation, Leiper's suggestion would seem to offer an effective method of control. The control of Japanese schistosomiasis in this way will prove more difficult on account of the resistance to drying of *Blanfordia nosophora.* The experiments outlined above show that this resistance is limited and wherever it would be possible to dry up breeding places for more than three months, the snails would be killed. Also even if the length of time of drying could not be carried to the full three months limit, some progress would be made on account of the reduction in numbers of the snails and the death of infected individuals.

CONCLUSIONS

1. The resistance to desiccation of *Blanfordia nosophora,* the intermediate host of the Japanese blood fluke, *Schistosoma japonicum,* is limited to about three months.

2. Desiccation unfavorably affects the cercariae within the snails and infected snails succumb more quickly than uninfected.

3. Individuals of *Blanfordia nosophora* will voluntarily leave the water and become dry under unfavorable conditions.

4. Measures for the control of Japanese schistosomiasis by draining the breeding places of *Blanfordia nosophora,* would be fully effective only if these places were kept dry at least three months.

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